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TECHNICAL NOTE

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Aluminum Company of America

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SUMMARY

A series of tests was made to determine the bearing yield and ultimate strengths of typical samples of 1/4- and 2-inch-thick plate of aluminum alloy 24S-T and to establish nominal ratios of bearing-to-tensile properties for the commercial range of plate thicknesses. The tests, which supplement previous tests of similar nature, indicate that the following ratios of bearing yield and ultimate strengths to specified cross-grain tensile properties are applicable to the various commercial thickness ranges of aluminum alloy 24S-T:

Edge distance in terms of pin diameter, D	Ratios of bearing yield and ultimate strengths to specified cross-grain tensile properties			
	Bearing-to-tensile ultimate for all thicknesses	Bearing-to-tensile yield for various thicknesses		
		Less than 0.249 in.	0.250 to 1.000 in.	1.001 to 2.000 in.
1.5D	1.5	1.64	1.6	1.5
2.0D	1.9	1.87	1.8	1.7

The foregoing values may be extended to cover Alclad 24S-T and 24S-RT plate.

INTRODUCTION

Although the ratios of bearing to tensile properties determined from with-grain tests of 0.064-inch 24S-T sheet (reference 1) have been generally accepted as a basis for the selection of allowable bearing design values for all

thicknesses of 24S-T sheet, there has been some question as to the applicability of these ratios to thicker materials. This is particularly true in the case of bearing yield strengths since the differences between with- and cross-grain tensile yield strengths for plate are not so well established as for sheet (reference 2). The bearing yield values specified by the Army and Navy for all thicknesses of 24S-T plate in reference 3, for example, were obtained by applying suggested ratios of bearing yield to with-grain tensile yield strengths to specified cross-grain tensile yield values and multiplying by a factor of 1.17, the ratio of with- to cross-grain tensile yield strength of 24S-T sheet, given in table I-1 of reference 2. The Civil Aeronautics Administration apply the same procedure for the determination of bearing yield strengths for 24S-T sheet but the 1.17 multiplication factor is omitted for all thicknesses of plate. In view of the appreciable difference between bearing yield strengths determined by these two procedures, it is obvious that a better basis for the selection of allowable design values is needed.

OBJECT

The object of this investigation was to determine the bearing yield and ultimate strengths of samples of 1/4-inch-thick and 2-inch-thick 24S-T plate and to establish, if possible, more satisfactory ratios of bearing to tensile properties for the commercial range of plate thicknesses.

This investigation was conducted by the Aluminum Company of America at the Aluminum Research Laboratories, New Kensington, Pa.

PROCEDURE AND MATERIAL

The procedure followed in these bearing strength determinations was essentially the same as that used in previous tests (reference 1). A photograph of the test arrangement is shown in figure 1. All specimens were originally 2 inches wide by 1/4 inch thick by 18 inches long and were loaded in bearing on a 1/2-inch-diameter steel pin. The specimens from the 2-inch-thick plate were taken midway between the center and outside, conforming to the usual procedure for material acceptance tests. Tests were made in duplicate for edge distances of 1.5, 2, and 4 times the pin diameter. Tests at all

three edge distances were made on each specimen by machining off the damaged end after one test (about 3/4 in. below the center of the hole) and redrilling at a new edge distance.

Table I gives the tensile properties of the plate used. The values for both the 1/4-inch and 2-inch thicknesses are above specified minimum values for plates of these proportions and fall within the range generally considered typical for 24S-T. The tensile strength of the 1/4-inch plate in the with-grain direction was about 3 percent greater than that in the cross-grain direction; whereas the corresponding difference in tensile yield strengths was about 16 percent. These ratios are consistent with the directional property differences given for 24S-T sheet in reference 2.

In the case of the 2-inch plate the with-grain tensile strength was approximately 10 percent greater than that in the cross-grain direction; whereas the tensile yield strengths in the two directions differed by only 3 percent. In view of the fact that tests were made of only one sample of 2-inch plate, there may be some question regarding the significance of the differences in tensile strengths obtained in the two directions. Previous tests of one experimental lot of 3-inch 24S-T plate have shown an even greater difference in the tensile strengths in the two directions although the same is not true of tests in one experimental lot of 4-inch 24S-T plate. The small difference in tensile yield strengths measured in the two directions in the 2-inch plate is consistent with the results obtained for the 3-inch and 4-inch-thick plates and seems to be a logical result of fabrication procedures. Stretcher leveling, which is responsible for some of the difference between with- and cross-grain tensile yield strengths, is generally not used for 24S-T plate in thicknesses greater than 7/8 inch. Tensile tests of 1/2-inch and 13/16-inch 24S-T plate indicate that the spread between with- and cross-grain tensile yield strengths may be considered to decrease about linearly with increasing plate thickness from the difference of 17 percent now accepted for 24S-T sheet (reference 2) to zero for plate thicknesses of 2 inches or greater.

RESULTS AND DISCUSSION

The individual bearing test results are shown in table II. The bearing yield strength values were obtained from the bearing stress-hole elongation curves shown in figures 2 to 5, using an offset from the initial straight-line portion of the

curves equal to 2 percent of the pin diameter. Also indicated in table II are the types of failure obtained. Failures by a combination of shear and tension in the margin above the pin were predominant for edge distances of 1.5 and 2 diameters. For the 4 diameter edge distance the cross-grain specimens failed by tension across the width of the specimens.

Table II shows that there was no significant difference between with- and cross-grain bearing yield and ultimate strengths for either thickness of plate. This result is consistent with that observed in previous bearing tests of sheet and emphasizes the fact that one set of ratios of bearing to tensile properties cannot be established for materials having marked directional properties in tension.

Ratios of average bearing to tensile properties are shown in table III. Included also for comparison are corresponding ratios obtained in previous tests of 0.064-inch 24S-T sheet as well as the ratios suggested as typical for this and certain other high strength alloys in the form of sheet (references 1 and 4). As far as ratios of ultimate bearing strength to tensile strength are concerned there is no appreciable difference between the ratios obtained for the three thicknesses of material. With the exception of those indicated for the with-grain direction in the 2-inch plate, all are within 5 percent of the suggested typical ratios for sheet and are substantially the same as those used currently in the selection of allowable design values (reference 3). The difference between with- and cross-grain ultimate strength ratios for the 2-inch plate reflects the 10-percent difference in with- and cross-grain tensile strengths obtained for this material. Unless more data substantiating this directional property characteristic of thick plate are obtained, however, the application of the present ratios of bearing ultimate to tensile ultimate strength to cross-grain properties for plate, as is now done (reference 3), appears to be a conservative and satisfactory procedure.

The ratios of bearing yield strength to tensile yield strength shown in table III for the 1/4-inch plate indicate the same type of directional property variations as have been previously observed for sheet although the ratios themselves are somewhat lower than suggested as typical for the thinner material. In the case of the 2-inch plate, however, there was no appreciable difference between the ratios of bearing yield to tensile yield strengths obtained in the two directions.

The interesting point to be noted is that these latter ratios, obtained from material having no appreciable difference in with- and cross-grain tensile yield strengths, are about intermediate between those suggested as typical for the with- and cross-grain directions of sheet. Although ratios of with- to cross-grain tensile yield strength for 24S-T plate are not yet established, it is believed that interpolation between the limits now accepted for sheet and those indicated by these tests for 2-inch plate may be used as a basis for the selection of bearing yield values. It seems quite evident that the procedure which has been described previously for obtaining ratios of bearing yield strength to cross-grain tensile yield strength for sheet from the results of with-grain tests should not be extended to plate materials showing less pronounced directional properties.

CONCLUSIONS

The results of this investigation of the bearing properties of 1/4-inch-thick and 2-inch-thick 24S-T plate are believed to justify the following conclusions:

1. The tensile properties of the materials used were within limits considered satisfactory for an investigation of the bearing strength characteristics of 24S-T plate. The directional properties of the 1/4-inch plate in tension were approximately the same as indicated for 24S-T sheet in reference 2. The tensile strength of the 2-inch plate in the with-grain direction was about 10 percent greater than that observed across-grain; whereas the corresponding difference in tensile yield strengths in the two directions was only about 3 percent.

2. Table II summarizes the bearing yield and ultimate strengths for all tests and indicates the types of bearing failures obtained. There was no significant difference in the bearing values obtained in the with- and cross-grain directions of either sample of plate.

3. The ratios of bearing ultimate strength to tensile ultimate strength shown in table III for both plate samples in the cross-grain direction are in good agreement with the ratios suggested as typical for 24S-T sheet in reference 1 and with those which are currently used in the selection of allowable ultimate bearing values for all thicknesses of 24S-T sheet and plate (reference 3). The following nominal ratios

are proposed, therefore, as being applicable to specified cross-grain tensile strengths of plate;

	Edge distance = 1.5D	Edge distance = 2.0D or greater
$\frac{\text{Bearing strength}}{\text{Tensile strength}}$	1.5	1.9

4. The ratios of bearing yield strength to tensile yield strength obtained for the 1/4-inch plate show directional property variations characteristic of 24S-T sheet although the ratios themselves are somewhat lower than those suggested as typical for thinner material. The ratios of bearing yield to tènsile yield strength for the 2-inch plate, however, are approximately the same in the two directions and are about intermediate between those suggested as typical for the with- and cross-grain directions of sheet. The practice of computing ratios of bearing yield strength to cross-grain tensile yield strength from the results of with-grain tests of sheet, using the ratio of with- to cross-grain tensile yield strength as a modifying factor, apparently should not be extended to plate materials having less pronounced directional properties.

5. It is proposed that ratios of bearing yield strength to cross-grain tensile yield strength for 24S-T plate, ranging from 1/4 inch to 2 inches in thickness, be estimated by interpolation between the ratios currently used for sheet and those indicated by these tests of 2-inch-thick plate. The following nominal ratios of bearing-to-tensile yield strength, applicable to specified cross-grain tensile yield strengths, are proposed on this basis for the various commercial thickness ranges:

Edge distance in terms of diameter, D	Thickness		
	Less than 0.249 in.	0.250 to 1.000 in.	1.001 to 2.000 in.
1.5D	1.64	1.6	1.5
2.0D	1.87	1.8	1.7

6. In view of the similarity of bearing strength characteristics observed for all grades and tempers of 24S sheet, it is believed that the findings of these tests of 24S-T plate may be extended to cover Alclad 24S-T and 24S-RT plate.

Aluminum Research Laboratories,
Aluminum Company of America,
New Kensington, Pa., December 9, 1944.

REFERENCES

1. Moore, R. L., and Wescoat, C.: Bearing Strengths of Some Wrought-Aluminum Alloys. NACA TN No. 901, 1943.

2. Strength of Aircraft Elements. Army-Navy-Civil Committee on Aircraft Design Criteria. (ANC-5), 1942.

3. Strength of Aircraft Elements. Army-Navy-Civil Committee on Aircraft Design Criteria. Amendment No. 1, Oct. 1943.

4. Moore, R. L., and Wescoat, C.: Bearing Strengths of Bare and Alclad XA75S-T and 24S-T81 Aluminum Alloy Sheet. NACA TN No. 920, 1943.

TABLE I

TENSILE PROPERTIES OF 24S-T PLATE

(J. O. No. 12-237)

Sample	Specimen direction	Tensile ultimate strength (psi)	Tensile yield strength (offset=0.2 percent) (psi)	Elongation in 2 in. (percent)
1/4-inch plate				
P973-1	Cross-grain	67,200	45,500	19.3
P973-1	With-grain	69,200	53,000	20.0
2-inch plate				
P973-4	Cross-grain	64,200	45,800	8.5
P973-4	With-grain	70,600	47,100	16.0

NOTE.- 1/4-in.-thick sheet-type specimens used for 1/4-in. plate; 1/2-in.-diameter specimens used for 2-in. plate.

See figs. 2 and 3 of "Standard Methods of Tension Testing of Metallic Materials" (E8-42), 1942 Book of A.S.T.M. Standards, pt. 1, p. 899.

TABLE II.- BEARING PROPERTIES OF 24S-T PLATE

Specimen direction	Test	Bearing strengths (psi): Edge distance = 1.5 × pin diameter, Ultimate	Yield[1]	Type of failure[2]	Edge distance = 2 × pin diameter, Ultimate	Yield	Type of failure	Edge distance = 4 × pin diameter, Ultimate	Yield	Type of failure
					1/4-inch plate					
Across-grain	1	100,000	67,500	TS	126,900	83,500	TS	148,600	86,500	T
	2	101,600	71,500	TS	128,300	83,000	TS	151,300	85,500	T
	Av.	100,800	69,500		127,600	83,300		149,950	86,000	
With-grain	1	98,900	66,000	TS	125,000	82,000	TS	148,800	88,500	B
	2	99,400	64,500	TS	126,300	81,500	TS	144,800	86,500	B
	Av.	99,150	65,300		125,650	81,800		146,800	87,500	
					2-inch plate					
Across-grain	1	103,400	71,000	TS	128,700	82,500	TS	147,100	89,500	T
	2	99,200	72,000	TS	124,500	83,000	TS	148,200	84,000	T
	Av.	101,300	71,000		126,600	82,800		147,650	86,800	
With-grain	1	105,400	73,500	TS	127,100	82,000	S	146,000	84,500	B
	2	99,600	72,500	TS	122,100	82,500	TS	144,200	84,500	B
	Av.	102,500	73,000		124,600	82,300		145,100	84,500	

NOTE.- All tests on 1/2-in. diameter steel pin (D/t = 2). All specimens originally 2-in. wide by 1/4-in. thick by 18-in. long. Those from the 2-in. plate were cut midway between center and face of plate.

[1] Stress corresponding to offset of 2 percent of pin diameter from initial straight line portion of bearing stress-hole elongation curves shown in figs. 2 to 5 (offset = 0.010 in. for 1/2-in. diameter pin).

[2] Type of failure:
- T - Tension on transverse section through pin hole
- S - Shear of plate above pin
- TS - Combination of shear and tension
- B - Bearing or crushing of plate above pin

TABLE III.- RATIOS OF AVERAGE BEARING TO TENSILE

PROPERTIES FOR 24S-T SHEET AND PLATE

Specimen direction	Edge distance = 1.5 × pin diameter		Edge distance = 2 × pin diameter		Edge distance = 4 × pin diameter	
	$\frac{BS}{TS}$	$\frac{BYS}{TYS}$	$\frac{BS}{TS}$	$\frac{BYS}{TYS}$	$\frac{BS}{TS}$	$\frac{BYS}{TYS}$
1/4-inch plate						
Across-grain	1.50	1.53	1.90	1.83	2.23	1.89
With-grain	1.43	1.23	1.82	1.54	2.12	1.65
2-inch plate						
Across-grain	1.58	1.56	1.97	1.80	2.30	1.89
With-grain	1.45	1.55	1.76	1.75	2.06	1.79
0.064-inch sheet[1]						
Across-grain	1.46	1.57	1.90	1.89	2.36	2.17
With-grain	1.45	1.44	1.85	1.68	2.27	1.89
Suggested typical ratios for sheet[2]						
Across-grain	1.53	1.64	1.94	1.87	2.35	1.99
With-grain	1.50	1.40	1.90	1.60	2.30	1.70

NOTE.- BS - Bearing strength
BYS - Bearing yield strength (offset = 2 percent of pin diameter = 0.010 in.)
TS - Tensile strength
TYS - Tensile yield strength (offset = 0.2 percent)

[1]Ratios from table IV, reference 1.
[2]Ratios from table V, reference 1.

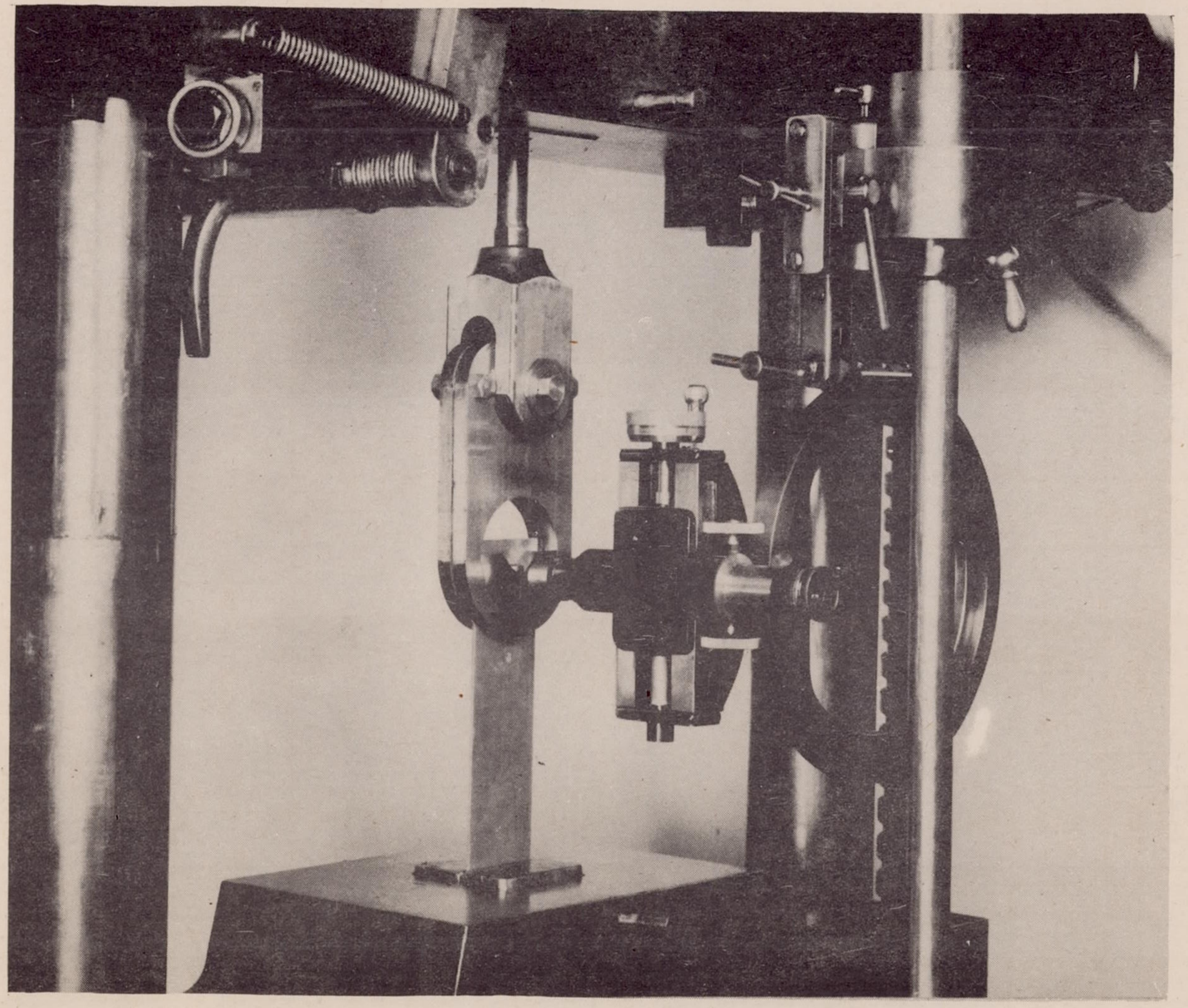
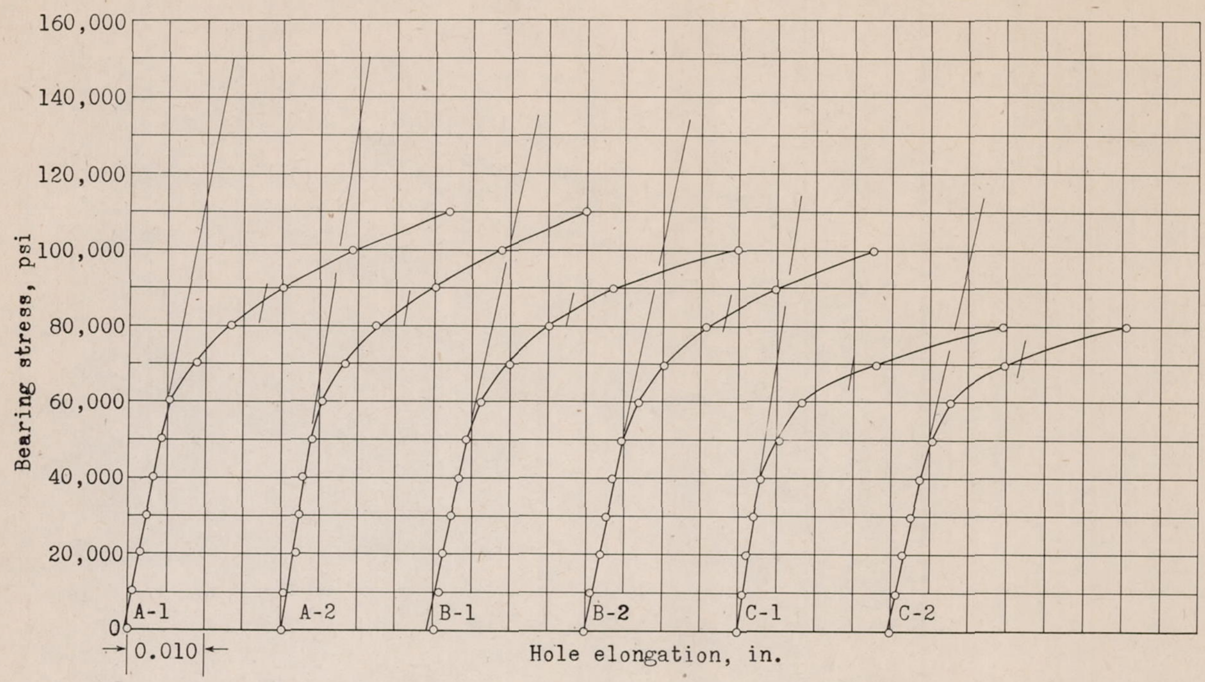


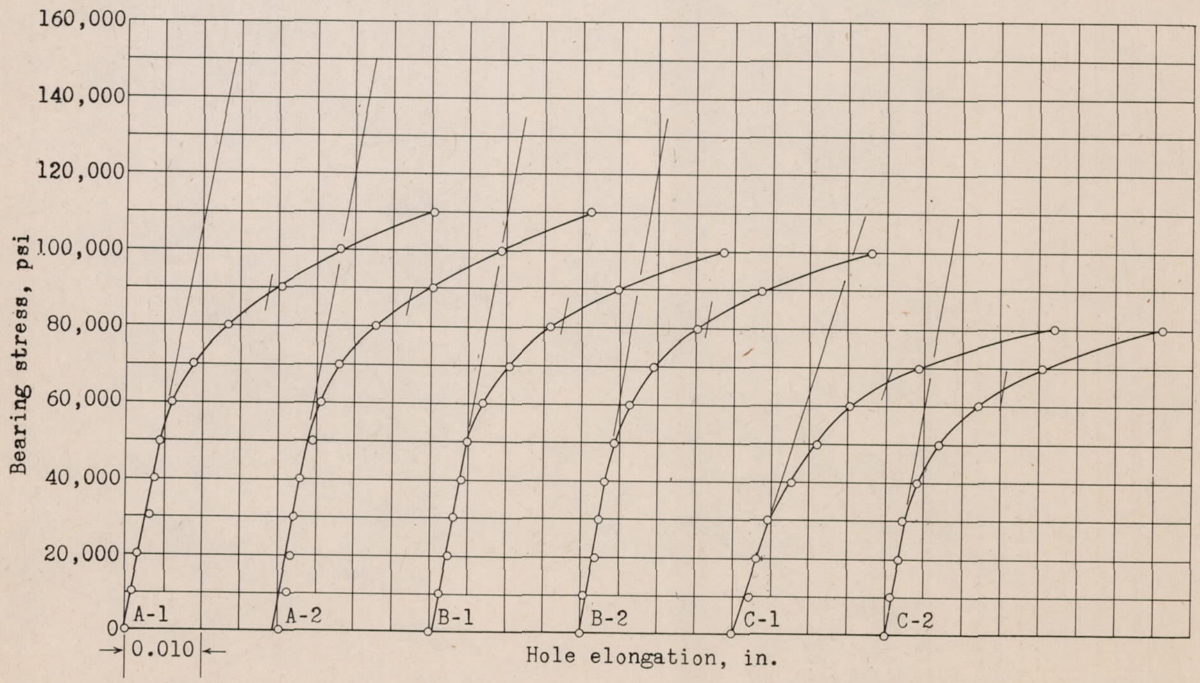
Figure 1.- Arrangement for bearing tests using filar micrometer microscope for measurement of hole elongation.



Pin diameter = 1/2 in.
Specimen thickness = 0.250 in.
Specimen width = 2 in.

A-1 and A-2: edge distance = 4 × pin diameter
B-1 and B-2: edge distance = 2 × pin diameter
C-1 and C-2: edge distance = 1.5 × pin diameter

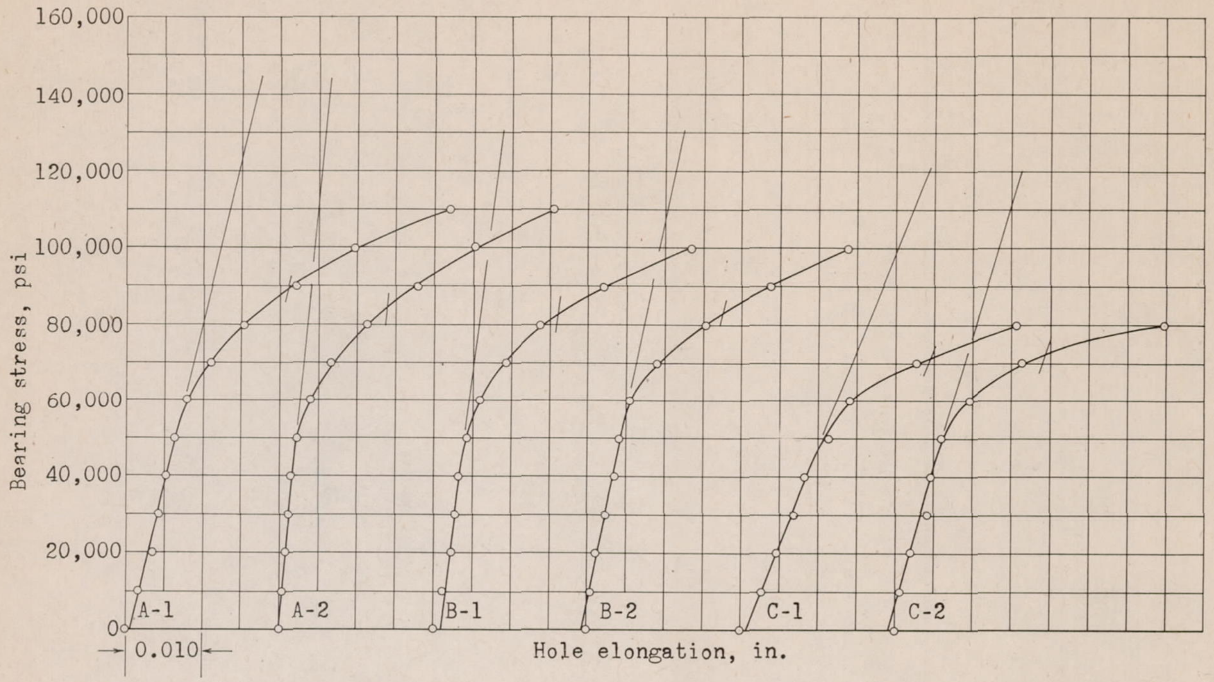
Figure 2.- Bearing stress-hole elongation curves for aluminum alloy plate, 0.250" 24S-T (X grain).



Pin diameter = 1/2 in.
Specimen thickness = 0.250 in.
Specimen width = 2 in.

A-1 and A-2: edge distance = 4 × pin diameter
B-1 and B-2: edge distance = 2 × pin diameter
C-1 and C-2: edge distance = 1.5 × pin diameter

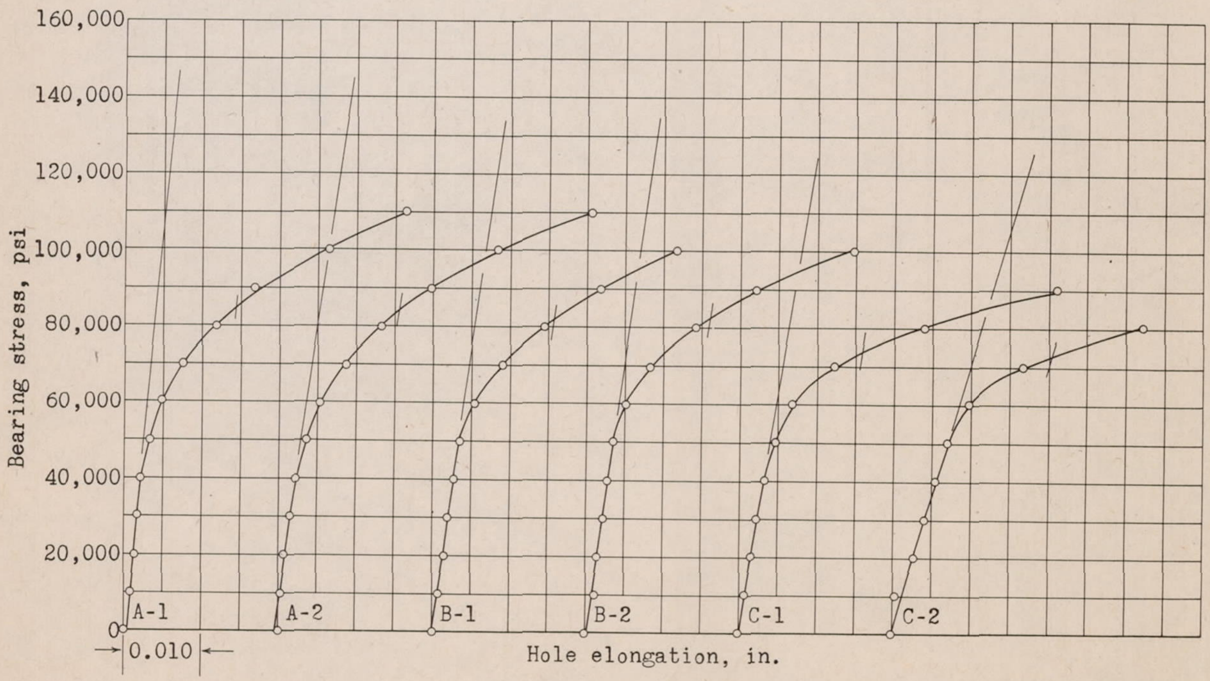
Figure 3.- Bearing stress-hole elongation curves for aluminum alloy plate, 0.250" 24S-T (W grain).



Pin diameter = 1/2 in.
Specimen thickness = 0.250 in.
Specimen width = 2 in.

A-1 and A-2: edge distance = 4 × pin diameter
B-1 and B-2: edge distance = 2 × pin diameter
C-1 and C-2: edge distance = 1.5 × pin diameter

Figure 4.- Bearing stress-hole elongation curves for aluminum alloy plate, 2" 24S-T (X grain).



Pin diameter = 1/2 in.
Specimen thickness = 0.250 in.
Specimen width = 2 in.

A-1 and A-2: edge distance = 4 × pin diameter
B-1 and B-2: edge distance = 2 × pin diameter
C-1 and C-2: edge distance = 1.5 × pin diameter

Figure 5.- Bearing stress-hole elongation curves for aluminum alloy plate, 2" 24S-T (W grain).